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HISTORY OF THE STRATOSPHERIC ROCKET IN THE USSR

M.K. Tikhonravov and V.P. Zaytsev

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16. Abstract

The article traces the development of the stratospheric rocket in the Soviet Union since 1933, when the first liquid-fuel rockets were launched. Various scientific organizations became interested in this new venture, but funds were often lacking and many projects were abandoned. The capabilities of rockets, in comparison with modern standards, were not extraordinary; heights of 2000-3000 meters were reached, with short flight times. The fuels used were mainly liquid oxygen and ethyl alcohol.

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HISTORY OF THE STRATOSPHERIC ROCKET IN THE USSR

M.K. Tikhonravov and V.P. Zaytsev

We shall call a stratospheric rocket one equipped with /1*
instruments and designed for flying into the stratosphere to study it. The idea of using such a rocket occurred almost simultaneously with the appearance of the first Soviet liquid-propellant rockets launched in 1933. The first rockets were designed and built, firstly, to fly and, secondly, to study the rocket's behavior in flight. Naturally, a possible practical use for the rocket was of little interest, and only the designer's final aim determined the purpose of his first rocket. However, it is difficult to categorize a rocket as being stratospheric, since almost every rocket can be launched vertically and can be equipped with any instruments. Therefore, in this report we shall only deal with rockets whose designers looked upon them as stratospheric or which were produced as stratospheric rockets according to the assignment and technical conditions. This group will also contain meteorological rockets, sometimes called registering rockets, which only differed from stratospheric ones by their lift.

The spread of the idea for building a stratospheric rocket was the result of reports and resolutions of the All-Union Conference on the Study of the Stratosphere, which took place in Leningrad from 31 March to 6 April 1934.[1] /2

At the conference it was proposed to investigate the upper atmosphere. It was pointed out that the main interest was the study of cosmic rays at great altitude. In the resolution for the technical section, it stated that "the conference believes it is necessary to concentrate the main efforts on developing equipment for taking instruments into the stratosphere using

*Numbers in the margin indicate pagination in the foreign text.

[1]See Ref. 1. Resolutions of this conference were published in a separate pamphlet in 1934 in Leningrad.

rockets as a transition stage towards designing rockets for manned flight."

Lectures at the conference were given by S.P. Korolev, Yu.A. Pobedonostsev, N.A. Rynin, A.N. Shtern and others. M.K. Tikhonravov devoted his lecture to "The use of rockets for investigating the stratosphere," in which he spoke of methods on the use of rockets for this purpose.

The rocket in question in the lecture was the 09 rocket of the Moscow Group for the Study of Jet Propulsion (GSJP). It was not intended to investigate the stratosphere when it was designed. It was only given in M.K. Tikhonravov's lecture as an example of producing a flying structure. This rocket will not be dealt with in the present report, devoted to rockets designed for entering the stratosphere. Neither shall we examine numerous rocket projects. We shall only deal with actual constructions which were built, even if they were not launched or even completed.

V.V. Razumov's rocket. One of the first rockets was the registering rocket of the Leningrad Group for the Study of Jet Propulsion, built by engineer V.V. Razumov. This group was organized at the Leningrad Society for Assistance to the Defense, Aviation and Chemical Construction of the USSR. /3

The rocket was built during the middle of 1934.[2] Figure 1 shows a schematic drawing and a longitudinal section of the rocket.

The following figures indicate the parts of the rocket: 1 - body, 2 - nose cone, containing a parachute and instruments,

[2] A short description of this rocket was contained in an article by N. Rynin [2], in an article by M.K. Tikhonravov [3]; and and also in the newspaper Leningradskaya pravda [4]

3 - stabilizers, 4 - liquid oxygen tank, 5 - insulation, 6 - liquid oxygen fueling valve, 7 - liquid oxygen piping, 8 - gasoline tank, 9 - gasoline fueling valve, 10 - liquid oxygen shut-off cock, 11 - gasoline shut-off cock, 12 - engine, 13 - liquid oxygen tank pre-valve, 14 - bulkhead, 15 - gasoline tank pre-valve.

The rocket engine of A.N. Shtern's construction was of the rotary-reaction variety. The choice here was one of the attempts to solve the problem of supplying fuel to the combustion chamber. It consisted of pipes, along which fuel passed to the engine, fixed along brackets, and the rocket engines were attached to the ends of these. The nozzles of the latter were cut obliquely so that the reactive force had a component in the horizontal plane, directed perpendicularly to the bracket. The brackets and engine were attached to a /4
bearing on the vertical axis. In this way, a rotary system was developed where centrifugal force supplied fuel to the engine. Figure 2 shows the schematic diagram of this supply. Apart from solving the supply problem, it was possible to rely on the gyroscopic effect of gyrating masses, useful from the standpoint of maintaining stability. The design of the engine was developed at the Air Equipment Design Bureau at the Leningrad Society for Assistance to the Defense, Aviation and Chemical Construction of the USSR.

The gross weight of the rocket was 90 kg, the weight of the construction was 36.2 kg (body 20.2 kg, engine 16 kg), fuel weight 22.39 kg (gasoline 4.89, oxygen 17.5 kg), and the payload weight was 31.41 kg. In this way, the fuel weight was only 25% of the rocket's gross weight, or 38%, not allowing for the payload.

The engine thrust was 200 kg at an exhaust gas velocity of 2000 m/sec. The maximum estimated speed of the rocket was 100 m/sec, the estimated lift was 5 km.

The rocket (Fig. 3), its drawing and individual engine components, produced by A.N. Shtern (a combustion chamber and nozzle), were shown at an exhibition during the All-Union Conference on the Study of the Stratosphere. The building of an engine for V.V. Razumov's rocket dragged on until March 1935. Serious complications were encountered and it was not completed. However, V.V. Razumov's rocket was successfully launched with a powder engine at the station of the Aerolitic Institute in Slutsk.

In Moscow, at the beginning of March 1935, on the initiative of the All-Union Aviation, Scientific, Engineering and Technical Society, a conference on jet propulsion was held, where V.N. Vetchinkin, S.P. Korolev, V.P. Glushko, Yu.A. Pobedonostsev, M.S. Kisenko, and A.V. Zagulin gave lectures. During this conference, on 2 March, M.K. Tikhonravov gave a lecture "The use of rockets for investigating the stratosphere,"[3] in which he showed the possibility, using existing technology, of attaining an altitude of up to 60 km. /5

Let us note that at this time the following organizations were developing stratospheric rockets or, to some extent, were interested in this:

1) The Academy of Sciences of the USSR,

2) The Scientific Research Institute of Jet Propulsion (SRIJP), the People's Commissariat of Heavy Machinery Manufacture (PCHMM), founded in 1933 on the base of the Moscow GSJP and the Leningrad Gas Dynamics Laboratory (GDL),

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[3]Published in the collection of articles, Ref. 5.

3) The Society for Assistance to the Defense, Aviation and Chemical Construction of the USSR,

4) The All-Union Aviation, Scientific, Engineering and Technical Society.

In the majority of cases, the rockets were built to develop /6 space technology in one way or another, but were not specially designed for investigating the stratosphere. All these rockets are of great interest for the history of the development of jet propulsion in the Soviet Union.

The SRIJP rocket. Of the rockets produced by the SRIJP, interesting from the viewpoint of studying the stratosphere with them, we shall examine the rocket designed by engineer V.S. Zuyev between 1933-1934. The V.S. Zuyev rocket was designed for a vertical climb up to 50 km. It was shaped like a cigar with four fixed stabilizers on the tail. It had tanks, a body and a tail unit. There was no engine or starting device. In this way, the rocket's components were not used, apart from some which were subsequently removed for a high-altitude rocket. Later on, a rocket was built with an 02 engine on the design of V.S. Zuyev's rocket, and it made flights.

A.I. Polyarnyy's rocket was built by a group of public-spirited persons interested in rocket technology who formed a special group within the Society for Assistance to Defense, Aviation and Chemical Construction of the USSR in Moscow. The rocket and engine were designed by engineer A.I. Polyarnyy, who began working with this group in the autumn of 1934. In view of the limited resources, A.I. Polyarnyy designed a relatively simple meteorological rocket (Fig. 4).

By the spring of 1935 the rocket with its engine was built, and at the beginning of the same year a test firing was held at /7

Nakhabino near Moscow; however, it was unsuccessful. The rocket, with its engine working, became wedged in the launcher and operated for a certain time until the fuel was exhausted. This occurred because a special key, which opened valves, was not removed soon enough after opening.

The rocket's engine worked on alcohol and liquid oxygen and developed a thrust of approximately 100 kg. The liquid oxygen was supplied by pressure from its own vapors, in the same way as the 09 rocket. The alcohol was fed under pressure, previously created in the tank.

Later, the rocket was given to Design Office No. 7, which was organized in the second half of 1935 (where A.I. Polyarnyy went to work). It became known as the R-06, was modernized and made many flights. However, it already had a different role.

<u>The All-Union Aviation, Scientific, Engineering and Technical Society rocket</u>. In 1935, there was still unused material from oxygen rockets at the SRIJP. Therefore, it was decided to build a rocket on the base of this material. The All-Union Aviation, Scientific, Engineering and Technical Society supported this initiative and granted 5000 rubles for this.

The rocket consisted of: a) a 12-k engine designed by L.S. Dushkin, with a thrust of 300 kg, ceramic, with an operation time of 60 seconds, working on liquid oxygen and 96% alcohol; b) an 05 GSJP rocket, designed by M.K. Tikhonravov in the autumn of 1933, with an ORM-Gas Dynamics Laboratory engine, /8
but was not used for a variety of reasons. Figure 5 shows a section of this rocket. However, stabilizers from the 05 rocket were replaced with stabilizers from the SRIJP rocket, designed by engineer V.S. Zuyev, which was not completed. The stabilizer wings were contoured and hollow. In this way, a rocket was

built with a launch weight of 100 kg, of which 32 kg were fuel. The engine mentioned above produced a specific thrust of 205-207 kg. The weight of the whole engine installation was 15 kg. It was estimated that the rocket would reach an altitude of 3800 m. The nose cone contained a parachute weighing 8 kg. The rocket was equipped with an instrument for measuring the lift, designed by S.A. Pivovarov and was a simplified barograph.

The first launch of the All-Union Aviation, Scientific, Engineering and Technical Society rocket took place in April 1936 at a proving ground from a launcher made for the SRIJP 07 rocket, designed by M.K. Tikhonravov. However, the rails of this launcher had been lengthened. "Pravda" carried a report of the launch with the title "A rocket goes into the air." There was also a photograph of the rocket before the launch in the launcher. This is how L. Brontman, a correspondent of the newspaper, described the rocket's flight: "The mechanic switched on the electrical primer. There was a gray cloud of evaporating fuel. A spark. Suddenly, a blinding yellow tongue of flame appeared at the bottom of the rocket. The rocket slowly moved upwards along the launcher guide rails, slipped from their steel clutches and hurtled upwards. The flight was an unusually effective and beautiful sight. A flame flew from the motor's nozzle, and the gas efflux was accompanied by a deep hollow roar. After reaching a certain altitude, the white parachute in the rocket opened and it descended slowly to the snow-covered field."

For further flights, a wooden mast was erected, similar /9 to 48-meter radio masts, with a guiding strip, which held the brackets -- the rocket's eccentric clamps (Fig. 6). A rail from a narrow-gauge railway served as a strip. This mast was used as a launcher on 2 August 1937; however, during the launch the maximum pressure gauge in the tanks did not work, and the launch was called off.

A successful launch took place on 15 August 1937, the rocket rose vertically and disappeared from view. When it fell back to Earth, the parachute opened, but became detached and the rocket disintegrated. The instrument for recording the altitude was found and its reading was 2400 meters. Since the instrument was installed inside the rocket, it can be assumed that this was the altitude when the parachute opened. The rocket was seen to rise higher than the point at which the parachute opened. Therefore, there is reason to assume that the rocket reached an altitude greater than 3000 meters.

The A.F. Nistratov meteorological rocket. This rocket was built completely, including the engine, during 1936 and 1937 in the workshops of the Scientific Research Institute of the Civil Air Fleet of the USSR, on funds of 5000 rubles, but was not tested (Fig. 7). Its engine was made from duralumin and cooled with water, which after entered the combustion chamber. The engine was to operate on liquid oxygen and oil. According to calculation, the addition of water, lowering the temperature, would have little effect on the thrust. The rocket was equipped with a parachute which opened automatically, and was ejected by a powder ejection charge.

The L.S. Dushkin and M.K. Tikhonravov rocket. This rocket was designed in 1937, and calculated to reach an altitude of 30 km. The project was not completed, but models of the rocket /10
were made and tested. Black powder rockets were used in the models. The powder rockets used were old ones, supplied to the Czarist army in Russia in 1916. The rocket's stability was tested with these models. Among various models used, mention must be made of some built on a design using a torus as the vessel for holding the tanks. In one version, a tank in the shape of a torus was made and tested for strength. The rocket itself was not built.

The L.S. Dushkin rocket. This was designed in 1937 and built in the following year. It had a gyroscopic instrument, designed by S.A. Pivovarov, and automatic control rudders on the stabilizers. The rocket had a removable nose cone with a parachute, an automatics compartment, and a tank section, between which there was a cartridge-pressure accumulator. This original method of fuel supply was developed in 1935. The rocket also used a ceramic 205 engine, designed by L.S. Dushkin, with a thrust of 150 kg, and had a metal nozzle. This engine was a further improvement of the 12 k engine. The rocket was designed for vertical lift-off. Its engine and supply system were developed on a test bench. One rocket was made, but four automatic control systems were produced. Since the rocket did not carry out tactical tasks, further finances were not available, and it was not produced.

The R-05 rocket. The construction of this rocket was initiated by O.Yu. Schmidt and was supported by the Geophysical Institute of the Academy of Sciences of the USSR. The rocket's /11 lift was to be 50 km. A rocket with such a lift also interested the Institute of Technical Physics (Leningrad) who wished to study space radiation with it.

The assignment for building this rocket, known as R-05,[4] was accepted by Design Office No. 7, and towards the end of 1937, a joint project for the rocket was made by A.I. Polyarnyy and P.I. Ivanov. The rocket had two powder starting chambers.

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[4] This rocket must not be confused with the GSJP 05 rocket. The numbering of objects at the GSJP was in two-symbol sequence: 01, 02, 03, etc., without any letters. The numbering of the No. 7 Design Office rockets was also in two-symbol sequence, but began with the letter R: R-01, R-02, R-03, etc.

In the summer of 1938, P.I. Ivanov carried out special work on stabilizing the rocket using a gyroscope, rigidly connected to the body inside the rocket. Six models were made. These were small liquid fuel rockets, consisting of ethyl alcohol and liquid oxygen. The model with the gyroscope weighed 12 kg. The rockets flew and gave satisfactory results.

A cartridge-pressure accumulator was developed for the R-05 rocket in 1937. It must be mentioned that the use of a cartridge-pressure accumulator was made possible in duralumin fuel tanks.

The rocket was designed to have an engine produced by F.L. Yakaytis, operating on liquid oxygen and 96% ethyl alcohol. The engine itself and the fuel supply system were developed in 1938. The engine had the following characteristics: thrust 185 kg at a specific thrust of 210 sec, burning time 25 sec.

The rocket itself was built in the same year. Its launch /12
weight with the powder starting chambers was 60.5 kg, the gauge 200 mm. The firing time of the starting chamber was 2.58 sec. The average thrust of one chamber was 200 kg. The tank capacity for liquid oxygen was 20.5 liters, and was filled to 85% capacity; the volume of the alcohol tank was 13 liters, filled to 91%. The pressure in the tanks during supply was 25-28 technical atmospheres.

Up to an altitude of 10 km, it was intended to use a source of infrared rays to maintain vertical trajectory, which would react upon photoelectric cells on the stabilizers. The automatically controlled rudders would keep the rocket in the narrow infrared beam. In 1938 the Ukrainian Physicotechnical Institute developed a system of photoelectric cells for this rocket. For organizational reasons, all work on the R-05 rocket ceased in April 1939.

However, at the beginning of 1940, supporting the initiative of the rocket's developers, the Moscow Higher Technical School (MHTS) agreed to complete the R-05 rocket, on the condition that a customer was found. The Hydrometeorological Service at the Council of People's Commissars of the USSR agreed to finance the work, but the war interrupted this.

<u>The P.I. Ivanov rocket</u>. In 1943, the Physics Institute of the Academy of Sciences of the USSR became interested in building a rocket for taking instruments to an altitude of up to 40 km to investigate the intensity of cosmic radiation. It was proposed to launch the rocket from the mountain station of the Academy of Sciences in the Pamir at an altitude of 4000 m. The assignment was accepted, and the design work began in April 1944. All the calculations and designs were done under the leadership of P.I. Ivanov and the participation of V.V. Abramov, and later, I.V. Yaropolov and were finished in June 1945. /13

In the October of that year, M.K. Tikhonravov, in whose laboratory design work had been carried out, gave a lecture at the Technical Council. In December, a report on the project was made by P.I. Ivanov, during a meeting at the Physics Institute im. P.N. Lebedyev of the Academy of Sciences, and with Academician S.I. Vavilov.

In both cases, the project was approved. In March 1946, it was decided to build ten rockets for the Physics Institute im. P.N. Lebedyev of the Academy of Sciences, by 15 May 1946.

The P.I. Ivanov stratospheric rocket belonged to a type of rocket with successive separation. The rocket consisted of three powder rockets (Fig. 8) with an internal chamber geometry of a 132-mm caliber rocket shell. The chambers were made from duralumin and connected in series. Ignition of the final stages was carried out by a slow-burning pyrotechnic compound compressed in a special tube. The external diameter of the rocket was 138 mm, the length of the whole rocket 3420 mm.

Powder rockets were chosen exclusively in order to produce a stratospheric rocket as quickly as possible. Subsequently, it was suggested to develop a liquid-fuel rocket.

A starting chamber, which lengthened the rocket to 4230 mm (Fig. 9), was used for increasing the speed at which it left the launcher to 100 m/sec, which had a guiding length of 10.5 m. The weight of the rocket with the launching chamber, and completely equipped was 87.2 kg. Without the launching chamber, the three-stage rocket weighed 62.5 kg. After jettisoning, the weight was reduced to 41.4 kg, and finally, to 22.1 kg, /14 respectively (with powder). The weight of the rocket, at the highest point of the trajectory, was 14.9 kg with instruments.[5]

The rocket would have attained an altitude of 48 km on the condition that the launch point was at an altitude of 4000 m. When launched from sea level, the lift would be 35 km.

Firings were made from the proving ground on 19 March 1946 to test decoupling and stability. A modification of the rocket was used with steel combustion chambers. The results were satisfactory. During the second half of June 1946, experimental firings were made of the P.I. Ivanov stratospheric rocket. The tests were carried out for economic purposes

[5] After the war ended, among German rocket equipment in 1945 there was a Raynbot powder, multistage rocket, which hardly differed in design from the P.I. Ivanov stratospheric rocket. The dates shown above indicated that the rocket was developed quite independently in the Soviet Union.

together with the Physics Institute im. P.N. Lebedyev of the Academy of Sciences, which was testing special equipment.[6] Three rockets were prepared for launch. The combustion chamber of one of them disintegrated at the launch, and the second changed course erratically when the chamber was disconnected. The center of gravity of the third was artificially moved forward and it flew well.

The lift height was determined by radar. Probably, this was the first attempt to use radar to determine the trajectory of a rocket. /15

The Physics Institute im. P.N. Lebedyev of the Academy of Sciences stopped using the rocket at the end of the summer of 1946 due to its lack of lifting power. By this time, work on liquid-fuel rockets had progressed considerably. These were able to reach greater altitudes, and could contain standard and large, heavy, modified pieces of scientific equipment.

[6] It must be mentioned that the maximum acceleration during the rocket's lift was 130 g, and that the instruments would have withstood this.

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